



Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at <http://about.jstor.org/participate-jstor/individuals/early-journal-content>.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

ICE WORK IN SOUTHEASTERN MICHIGAN.

OUTLINE.

Introduction.	Early Wisconsin.
General topography.	Iowan
Surface topography.	Illinoian.
Rock topography.	Rock shattering.
Drift of the region.	Scorings in Monroe county.
Till.	Eastern portion.
Moraines.	Central portion.
Ice action in Wayne county.	Western portion.
Late Wisconsin.	General considerations.

INTRODUCTION.

OWING to its geographic position, lying directly athwart the southwestward movement of the great Laurentide ice-sheet, with the maximum extent of international boundary, far enough distant from the great center of ice accumulation as well as from the southern limit of its movement, the state of Michigan must theoretically have borne the brunt of the Canadian ice invasion. Surrounded as is no other state by rock-basins, only partially occupied by our present Great Lakes, the evidence is not wanting that the Laurentide ice operated with exceptional vigor over the two peninsulas and the adjoining regions. So far as at present known, the most extensive and interesting exposures of ice activity within the state are to be found in the southeastern counties of Wayne and Monroe, bordering Lake Erie and the Detroit River. The following report upon this region is based mainly upon work carried on for the Michigan Geological Survey and is here published with the consent of State Geologist Dr. Alfred C. Lane. The series of Huron-Erie moraines, which lie to the west of the Upper Maumee beach in Washtenaw and Lenawee counties, as well as the beach itself, were traced upon the accompanying map from field maps of Mr. Frank Leverett, to whom the writer is indebted for many suggestions concerning the interpretation of the glacial features of this region.

GENERAL TOPOGRAPHY.

Surface topography.—With the exception of the extreme north-western corner of Wayne, the two counties especially considered here were under the waters of the series of glacial lakes Maumee, Whittlesey, and Warren, which were ponded back by the

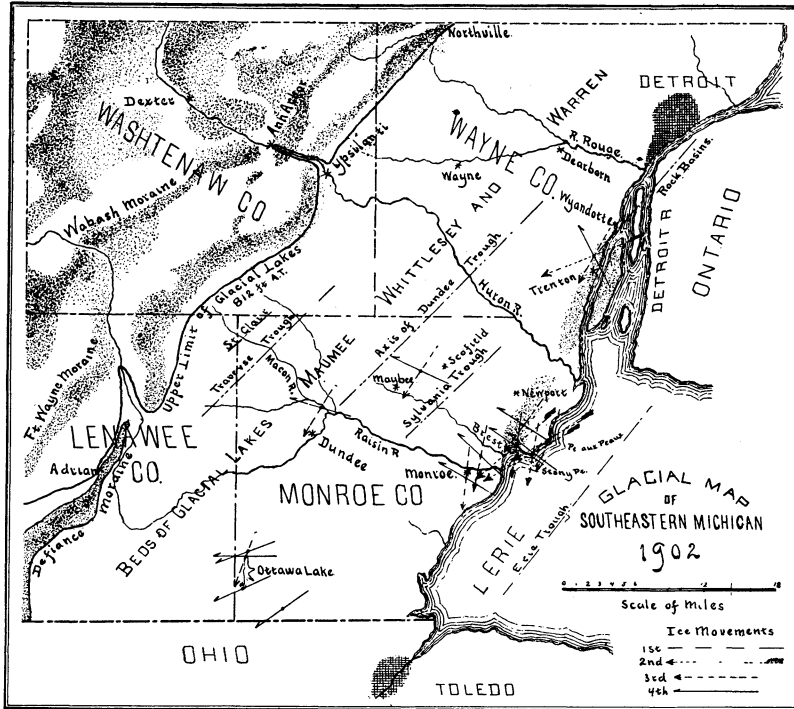


FIG. 1.—Glacial map of southeastern Michigan, showing the general directions of the four movements of the Laurentide ice. The upper limit of the glacial lake waters and the moraines to the west were located from the field maps of Mr. Frank Leverett.

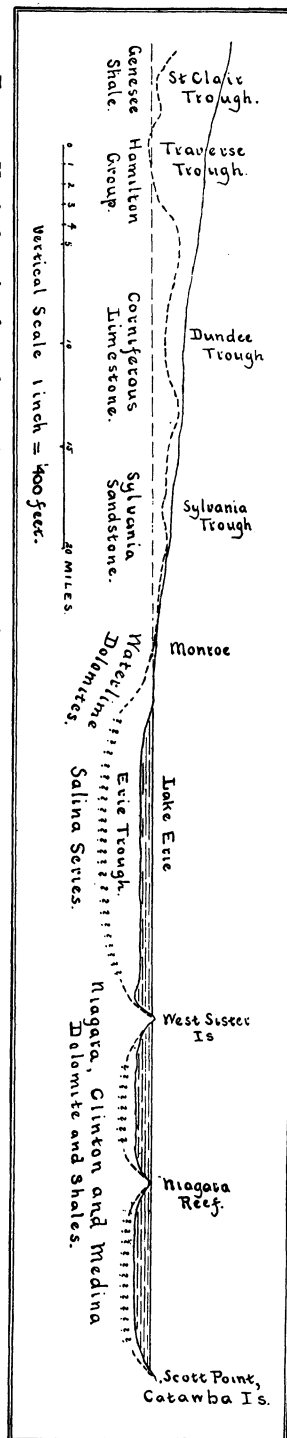
late Wisconsin ice as it slowly retreated to the north and east. The result of this was that the surface elevations left by the ice-sheet were, in the main, leveled by the waves and currents while the depressions were silted up and there was produced a remarkably flat topography, the slope of which is discoverable only by the surveyor's level or the small streams which meander over this plain. The general surface rises very gently, six to seven

feet to the mile, from the level of Lake Erie (573 feet A. T.) outwards towards the Belmore beach. The evenness of this slope is shown in the left half of Fig. 2, although the slope itself is much exaggerated by the vertical scale adopted. This Belmore beach, which was made by the waves of glacial Lake Whittlesey, has a northeast and southwest course in this region, parallel with the Detroit River and present beach of Lake Erie and some eighteen to twenty-five miles inland. For over three-quarters of a century this "ridge" has been recognized as marking a higher stage in the lake waters, but it seems to have been the only one which was so recognized. The position of the Upper Maumee beach, recently traced by Leverett, is shown in Fig. 1, marking the highest limit of glacial waters. The elevation of this beach, just west of Ypsilanti, was determined during the past summer by the United States Topographical Survey as 812 feet, A. T. Between these two beaches there is a strip varying in breadth from two to six miles, having an average slope upward and outward of twelve to thirty feet to the mile. Throughout this narrow strip the topography is more uneven, the morainic hills not having been completely obliterated by the waters of glacial Lake Maumee, thus testifying to its limited breadth in this region, or to its short duration. To the west of the Upper Maumee the land becomes markedly morainic, due to the crowding together of the various members of the Huron-Erie series, which are entirely separate in Ohio and Indiana. Some of the knobs in the northwestern part of Washtenaw county attain a height of 1,000 to 1,100 feet, A. T.

Between the Belmore beach (739 feet, A. T.) and the present Erie beach there are found three approximately parallel belts of sand which mark different stages in the history of glacial Lake Warren. In certain sections this sand has been scattered by the winds and tossed into dunes, which give some relief to this otherwise flat topography. Three small river systems, the Rouge, Huron, and Raisin, have been developed since the retreat of the ice, and drain this region to the southeast. A few small creeks reach the lake and the Detroit River independently.

Rock topography.— Throughout the main region under discussion the bed rock consists, in descending order, of Genesee shale (St. Clair), Hamilton shale and limestone (Traverse), Corniferous limestone (Dundee), and Waterlime dolomite with an intercalated bed of very friable sandstone (Sylvania). The strata have a general northeast and southwest strike and dip to the northwest at an angle of two to five degrees. An embossment of rock, ten to twenty miles broad, underlies the greater part of Monroe county, and extends northeastward into Wayne, gradually dropping toward Detroit. The highest elevation attained by this bed rock is about 680 feet, at the head of Ottawa Lake, southwestern Monroe county. Upon the broad crest of this embossment are carried three minor ridges, one in the eastern part, another in the central, and the third toward the western part of the two counties. These ridges seem to correspond with the strike of the layers, and presumably consist of somewhat harder rock. They furnish the various natural and artificial exposures now available for study, the most northern of which is at Trenton (see Fig. 2).

Fig. 2.—Vertical section from the northwestern corner of Monroe county, through Monroe to Scott Point, Catawba Island. The full line represents the surface of the land and the lake bottom; the broken line represents the rock surface, so far as it is known. Based upon the Lake Survey charts, railroad elevations, and individual well records.



Between these ridges lie two broad, shallow troughs, which have been named from the geological beds out of which they have been carved, the Dundee and the Sylvania.¹ The trend of these trough-like valleys is indicated upon the map, and also their extent, so far as recognized. The Dundee is the more pronounced of the two, having a breadth of two to four miles, and sloping downward towards Detroit at the average rate of four to five feet to the mile. Towards Dundee it is broader, and less well defined, as shown in Fig. 2. It seems to have been carved from the richer and softer strata of the Corniferous limestone, but in Wayne county it continues its direct course, while these strata are deflected eastward. Were it not for the deposit of drift, this trough would be filled with an arm of the lakes as far south as the southern boundary of Wayne county, standing one hundred feet deep at Detroit. The Sylvania trough begins in the west-central part of Monroe county, cutting eastward across the Waterlime dolomite until it strikes the outcrop of Sylvania sandstone, when it turns northeastward and becomes more accentuated in that portion which lies parallel with the Dundee. The valley then follows the strike of the Sylvania sandstone eastward and flattens out. In the northwestern part of Monroe county there occurs a double trough cut from the Genesee shale and the Hamilton shales and limestones, the latter being the best defined and having the same general direction and slope as the Dundee trough. The slope northeastward averages some nine feet to the mile so far as it has been followed in the well records. Were the drift removed, this trough would also be filled with water to a distance of three to four miles into Monroe county.

In the southern half of the eastern part of this county the rock surface drops rather rapidly towards Lake Erie, although the rock strata dip in the opposite direction, thus showing that much material has been removed by some agencies. The drop averages twenty-five to thirty feet to the mile, bringing the rock surface about one hundred feet below the Erie level by

¹ *Geol. Surv., Mich.*, Vol. VII, Pt. I, 1900, p. 122.

the time the lake is reached, forming the western slope of a very much larger trough underlying the western end of Lake Erie. An inspection of the Lake Survey chart shows that the eastern slope of this broad trough is terminated by a rock-ridge upon which are located West Sister Islands and Middle Sister Islands, running S. 35° W. Northeastward, towards the Ontario shore, occur Colchester reef and other rock. Toward the southwest this broad trough is continued beneath Toledo for a long distance as the Maumee trough, which would be filled with water were the drift removed, standing one hundred feet deep at Toledo, and extending seven miles further west than at present along the Ohio-Michigan line. Eight miles east of the ridge above-mentioned there occurs a second one running across the lake S. 32° W., and indicated by Niagara reef, East Sister Islands, and several other shoals and reefs. Between these ridges a second trough reaches across the lake, having its axis parallel to all the others. Beyond the second ridge, and between it and the string of islands which stretches continuously from Catawba Island northeasterly to Pointe Pelée, there is a narrower and less well-defined trough, but parallel to the two other Erie troughs. The position of this series of troughs, their direction and approximate parallism, their shape, and, so far as known, their direction of slope toward the northeast, all suggest that the primary agency was ice, acting with exceptional vigor straight out from the center of Laurentide accumulation. It so happened that the strike of the rock-strata in this region coincided with the main axis of ice movement, and the troughs in all cases were formed in the softer beds. It is not improbable that preglacial streams occupied some of these valleys, as in the case of the Sylvania, and that where the valley had the same trend as that of the ice movement it received the maximum ice erosion. The ice mass appears to have been too great at this stage to permit of its following the valleys when they turned aside from its general course. We seem to have here, but on a much larger scale, a similar phenomenon to that observed by Gilbert in western New York.¹

¹ *Bull. Geol. Soc. Am.*, Vol. X, p. 121, 1899.

DRIFT OF THE REGION.

Till.—A mantle of typical Wisconsin till covers the rock, except over the limited areas where the rocks are naturally exposed, or where it has been artificially removed about the quarries. This would average from forty to fifty feet in thickness in Monroe county, and perhaps seventy-five to eighty feet in Wayne. In the Traverse trough the drift is 140 to 150 feet thick, somewhat less beneath Detroit and Windsor. Westward toward the Defiance moraine the till thickens in Washtenaw county to two hundred feet west of Ypsilanti. We have no evidence of more than one sheet of this till. Occasional well records in southern Wayne and northern Monroe counties speak of seams of a black, combustible substance, generally referred to as "coal," but no continuous layer of black soil or peat exists. "Hard-pan" is not infrequently mentioned, and it is not improbable that isolated patches of early Wisconsin or pre-Wisconsin till may have escaped the late Wisconsin ice. At present writing, the twelve-foot shaft of the Michigan Rock Salt Co. has just penetrated seventy-one feet of till at Ecorse, just south of Detroit. This section gives four feet of muck; two feet of mucky clay; four feet of a mottled lake clay, yellow, brown, and blue in color, with shells, but no pebbles; and some seventy feet of soft, bluish-drab till, carrying pebbles and boulders. The only break in this sheet of till was found at a depth of thirty feet, where a six to eight-inch layer of gravel was encountered. In certain regions the till may be discolored to a depth of several feet, the maximum being fourteen, as reported at Dundee. Generally, blue clay can be found quite near the surface. Boulders are distributed sparingly over the two counties, lying upon the surface or embedded in the deposits from the glacial lakes. Huge masses of limestone, of the nature of "transported ledges," have been found in the till and mistaken for outcrops of bed rock.¹

¹ WINCHELL, "Some Indications of a Northward Transportation of Drift Materials in the Lower Peninsula of Michigan," *Am. Jour. Sci.*, 2d ser., Vol. XL, pp. 331-38. Also *Geol. Surv. Mich.*, Vol. VII, Pt. I, p. 22.

Moraines.—The moraines of the region mapped belong to the Huron-Erie series, and have a northeast and southwest direction. The most easterly and youngest is a water-laid moraine consisting of continuous and very symmetrical till ridges from five to twenty feet in height. They make their appearance between Wyandotte and Trenton, swinging in from the islands of the river, and they may be followed southward to within a mile of the Huron River. South of the river the moraine is indicated only by an unusual bunching of cobblestones to the east and southeast of Newport. In the vicinity of Brest there is a suggestion of morainic topography, the ridges running eastward into the lake and apparently marking the southern limit of this moraine. This is probably Taylor's Detroit moraine,¹ although it has not yet been followed into Ontario. The Defiance moraine lies just west of the Upper Maumee beach, the position of which it determined in this region. It is a relatively narrow moraine of comparatively weak expression, containing low knobs of sand and gravel, some of which were submerged by glacial Lake Maumee. Westward, the members of the Huron-Erie series become more and more massive, and so crowded that they cannot with certainty be distinguished from one another. Between them lie outwash gravel plains and ancient drainage channels, through which the water from the ice escaped to the west.

ICE ACTION IN WAYNE COUNTY.

Late Wisconsin.—Although there are rock exposures upon the islands of the Detroit River and near Gibraltar, still the surface of the waterlime dolomite is so much weathered that the striæ are entirely obliterated. Undoubtedly they are preserved under the heavier covering of till, but these portions of the rock-surface have not yet been exposed. The most favorable locality in the county for the study of glaciated rock is at the extensive Sibley quarry, operated by Church & Co., one mile north of Trenton, and about fourteen miles south of Detroit.²

¹ JOUR. GEOL., Vol. V, No. 5, 1897, p. 423.

² The station "Sibley's" may be reached from either Detroit or Toledo very conveniently by either steam or electric cars.

The rock here consists of heavily bedded and remarkably pure Corniferous limestone which is being quarried for building purposes, road metal, and the manufacture of beet sugar and soda ash. Some thirty-five acres have been opened about which there is always to be seen a variable margin of glaciated surface from which the till has been stripped. A huge embossment of rock here represents the northern terminus of one of the rock ridges described previously. The rock surface dips in all directions from the crest, but less rapidly towards the southwest, so that conditions were most favorable here for receiving and recording the effects of any ice-sheet moving across this region from the west, north, or east.

The marginal strip of rock surface, nearly a mile in length, shows pronounced glaciation by the late Wisconsin ice-sheet. The limestone has been planed down, striated, and gouged, and to a slight extent polished, but there are no furrows. The striæ and gouges have a rather unique northwestward direction, forty-eight observations about the quarry giving an average of N. 28.8° W. (true reading), with a range of 43° (N. 43.5° W. to N. 0.5° W.). The general appearance of the rock surface, with its intersecting gouges, is shown in Fig. 3.

The direction of ice movement is fully attested by a variety of phenomena, which were all clearly described by Chamberlin in 1888.¹ Striæ are frequently found of the nature of the one shown in Fig. 3, beginning as a fine scratch, passing gradually into a gouge and ending abruptly toward the northwest, as the stone was suddenly crushed. Projecting masses of the bed rock were bruised and scratched upon the southeast side, while the northwest side is rough and unglaciated. "Chatter-marks" are numerous with their convexities invariably turned toward the southeast and "plucking" is frequently to be seen upon the northwestern side of the elevated ledges. Previously formed furrows which have a northeast-southwest direction have their northwestern sides bruised and rounded, while the southeastern sides of these furrows meet the general rock surface with a well

¹ *Seventh Ann. Rept. U. S. Geol. Surv.*, p. 244.

defined angle and generally retain the earlier set of striæ. The most interesting and conclusive of all these evidences of the direction of ice movement is that of the so-called "knobs and trails."¹ These are now to be seen on the northern and north-eastern sides of the quarry, and five years ago also upon the southern side. Certain layers of the limestone contain silicified



FIG. 3.—View of the late Wisconsin glaciation, Corniferous limestone, Sibley quarry, showing parallel and intersecting striæ and gouges. Looking northwest in the direction of ice movement. At the right of the small satchel is a gouge fourteen feet long, N. 20° W., which begins as a pin-scratch but gradually broadens north-westward, expanding distally to four inches and terminating abruptly.

fossils and irregular nodules of chert. On account of their superior hardness these were worn away less rapidly by the ice than the limestone in which they are embedded and consequently they project above the surface. On the northwest side of many of these knobs there are found "trails" of limestone which diminish in height gradually to the general surface of the lime-

¹ GILBERT, *Geol. Surv. of Ohio*, 1873, Vol. I, p. 539.

stone but maintain the breadth of the protective knob. This phenomenon is shown quite clearly in Fig. 4. As a rule narrow and relatively deep furrows were plowed out in front of and at the sides of the knobs, the lateral furrows being prolonged a considerable distance backward before they disappear. Of the



FIG. 4.—“Knob and trail” phenomena produced by the late Wisconsin ice-sheet, testifying positively to the direction of northwest movement. Northern part of Sibley quarry. The main central gouge shows “chatter-marks” indistinctly in its lower half, while in the upper part of the view there are evidences of “plucking.” A shallow, tortuous groove crosses the left hand portion of the slab, cut subsequently to the glaciation by a small stream of water flowing between the rock and the till covering.

various properties imputed to ice for the purpose of explaining the movement of glaciers, *plasticity under pressure* can alone satisfactorily explain this phenomenon of “knobs and trails,” with their frontal and lateral grooves.

Associated with this late Wisconsin glaciation, but slightly later and cutting across it some 18° further to the west, as though made by a slight advance of the ice, is an erosion feature not known to have been previously noted. This is to be seen at the southwestern corner of the quarry, where it will be destroyed in a few more months, as the quarry is being extended in that direction. This consists of patches of miniature rock basins and narrow grooves, crowded together, in approximately parallel positions and covering some three to four square yards, so far as at present exposed. The limestone here is shattered, but essentially homogeneous, and has the appearance of a pavement formed of irregular blocks with edges rounded. The patches of basins are more conspicuous upon those blocks which are slightly higher than their neighbors and are better defined toward the stoss side of the blocks. It was found impracticable to get the basins to show satisfactorily in a field photograph, in which the lighting could not be controlled, so plaster casts were made of a number of patches for detailed study. Fig. 5 gives a reduced view of a cast, with the mold from which it was made at the left.

The basins are typically of a more or less elongated elliptical shape, sharply outlined, rather shallow and have the steepest slope toward the iceward side. The distal sides of the basins show a more gradual slope up to the general rock surface. The deepest part of the basin is either at the center, or placed nearer the iceward end, as is the case with the larger rock-basins of heavily glaciated regions. Some of the basins can be observed only with the help of a magnifier, while the largest noted has a length of 35^{mm} , a breadth of 15^{mm} and depth of 2^{mm} . Considering those of all sizes they are very numerous and closely placed, occasionally overlapping and superposed. The interiors of these basins are very generally perfectly smoothed and slightly polished, although with a magnifier delicate scratches may be detected. Occasionally some are seen which appear rough and have a bruised appearance. Some of the basins become elongated into U-shaped troughs, which may be either straight or curved. In the case of the curved ones the slope is

much steeper on the concave side, with a well defined crest, while that upon the convex side of the curve is less steep and flatter. This is the reverse of what we find in the case of stream erosion. In places these troughs have the appearance of branching and anastomosing, but this is probably due to the overlap-

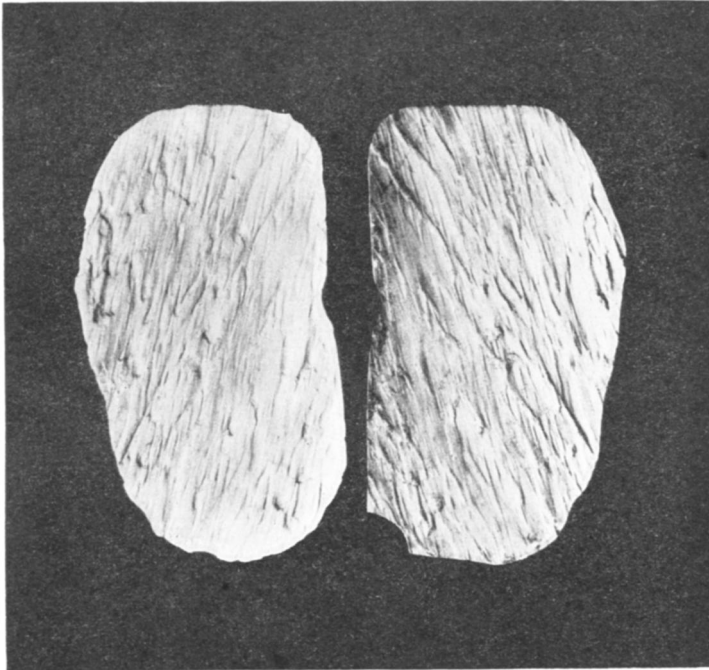


FIG. 5.—Mold and cast of a patch of miniature rock-basins, Sibley quarry. The ice movement was from above, downward. The continuous parallel grooves which pass diagonally across the cast were made by the preceding (late Wisconsin) ice movement, but were slightly emphasized by the movement which produced the basins. Careful examination of both the cast and mold will show that the miniature ice currents were deflected by these grooves for a short distance, but that the general direction was then resumed.

ping of those which have the curved form. Indeed, we have here in miniature glacial canyons, fjords, and a great variety of rock-basins, showing all their essential characteristics. If these have been difficult to account for satisfactorily how much more

so will be these toy affairs, for which differential ice action can scarcely be invoked! Pebbles embedded in the ice do not come into action suddenly and do not thus gouge the rock. Hard pebbles from about which the clay may have been washed and upon which the ice during its slight readvance may have settled could hardly have been thus forced into the limestone by the plastic ice. If the ice was not plastic then what became of these pebbles, there being no evidence of their having been crushed in the basins or troughs? These are some of the difficulties the writer has encountered in trying to arrive at an explanation of the phenomena.

Early Wisconsin.—Previous to the glaciation just described there was a general and more vigorous movement south-south-west across this region, which must be referred to the early Wisconsin stage. On the north side of the quarry there are to be found “lee and stoss” phenomena, “knobs and trails” and the above described effect upon the distal side of previously formed furrows. The general effect upon the rock surface was very largely obliterated by the late Wisconsin ice and the striæ and gouges are preserved mainly in furrows made by this earlier sheet itself or in those already in existence when it invaded this region. The mean of twenty-one observations taken on all sides of the quarry gives for the general direction of movement S. 30.8° W., with a range of 19.5° (S. 20.5° W. to S. 40° W.). This direction makes an angle of 120° with that of the late Wisconsin in this vicinity, it is manifestly older and there is evidence that it acted more vigorously, was presumably more massive and capable of reaching further south.

Iowan?—A still earlier set of striæ than that above described is to be seen in certain rock-basins and troughs partially exposed at the northeastern part of the quarry, and in some of less size at the southeastern part. At the time of a visit to the quarry five years ago a few readings were made in a trough which has been since partially removed, these readings averaging S. 64° W. During the past fall fifteen additional readings gave a mean of S. 68.6° W., with a range of 12.5° (S. 65.5° W. to S. 78° W.).

Most of these were made at the southwestern end of a partially uncovered rock-basin, or trough, across which they cut in such a way as to show that the basin was already in existence when they were formed upon its distal side. The striæ are shown in Fig. 6, emerging from the basin toward the right and diagrammatically in Fig. 7, upon the upper side, marked second move-



FIG. 6.—Southwestern end of a rock-basin, Sibley quarry; partly filled with till and water. Two sets of striæ are seen emerging from the basin; the set at the left being early Wisconsin, that toward the right pre-Wisconsin, probably Iowan. The basin itself is believed to have been formed by the Illinoian ice. In the background is seen the effect of the late Wisconsin upon the projecting ledge, with stoss phenomena toward the southeast.

ment. An inspection of this diagram shows why they were not obliterated by the third, or early Wisconsin ice, being slightly in the lee of the western side of the basin. They are here intersected sufficiently, however, in order to settle the question of their relative age. Their position is such as to have rendered their removal probable by the late Wisconsin ice, but either its

weight was not great enough to force it into the basin sufficiently, or else the basin was filled with till. So far as observed the evidence is that the ice producing these striæ acted less vigorously than did the early Wisconsin sheet. It does not seem to have produced any furrows or troughs of sufficient size to escape obliteration at the hands of the two later sheets. There may be a question as to whether this set of striæ should not be connected with the early Wisconsin described. Its general direction of movement differs, however, by some 38° and the two sets lack 25° of coinciding at their limits. Undoubtedly a larger number of readings would tend to connect the two series in this region, but further south they diverge still more widely. In the rock-basin figured this set lacks that freshness of appearance which characterizes the Wisconsin scorings and it is believed to be pre-Wisconsin, probably Iowan. The general direction of movement harmonizes with what is known concerning the distribution of the Iowan drift, its relative age and the intensity of ice action are also consistent with this view. Further, the Iowan ice is known to have crossed this region, and such an independent sheet would have been much more liable to have left its record than would simply a minor advance of either the early Wisconsin or the Illinoian.

Illinoian.—At the northeastern corner of the Sibley quarry there is at present a series of partly uncovered rock-basins, one of which is shown in Fig. 6. This has an apparent breadth of twenty-five to thirty feet, is eight to ten feet deep and some eighty-five to ninety feet of its length are in sight. There are four other basins, or troughs, in this same vicinity having with this one the approximate directions S. 37° W., S. 54° W., S. 39° W., S. 36° W., and S. 43° W. A small one running S. 17° W., belongs more probably with the preceding stage of glaciation. At the southeastern corner of the quarry a heavy double furrow running S. 45° W., contains pre-Wisconsin striæ and is to be included in the series. The average trend of these basins is found to be S. 42° W. These basins lie upon the stoss side of the Sibley embossment, where they were plowed out by

the ice as it was forced up and over the slope. The rock here is of uniform hardness over the area affected so that the basins were the result of differential ice action. A glance at Fig. 1 shows that the general direction of these basins corresponds perfectly with that of the troughs previously described, and the

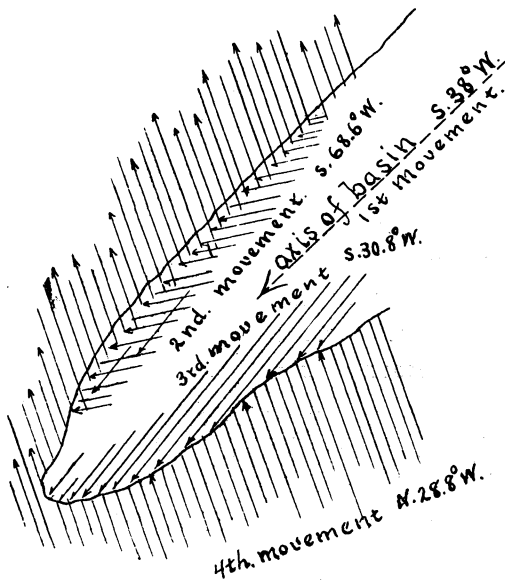


FIG. 7.—Diagram of the principal rock-basin at present exposed at the Sibley quarry. The arrows indicate the direction of each general movement, numbered in order from the first, or Illinoian. The central part of this basin is still covered with till.

conclusion is irresistible that they were all made by the same ice-sheet, which moved very steadily straight out from the center of Laurentide accumulation to the southernmost limit of glaciation in southern Illinois. It is apparent that this sheet acted with a vigor far in excess of that of any previous sheet, that it showed an utter disregard of topography; indeed, it seems probable that it had more to do with the *making* of our present rock topography, than the

other three sheets combined. These facts suggest that it was the most massive of the Laurentide sheets and presumably able to reach a more southern latitude than any of the other three, that it was in reality the Illinoian. The following diagram will serve to make clear the relation of the striæ to the principal basin.

Rock-shattering.—It has been observed in all the quarries and natural exposures in southeastern Michigan that the upper three to five feet of limestone strata are much shattered and apparently thin bedded. The strata become more solid and have the

appearance of being more heavily bedded as they occupy a deeper position in the series. The same stratum dipping from the surface may have the disrupted condition just beneath the till which is shown in Fig. 8 and still be as solid and compact at a depth as the lower strata shown in this figure. This condition of the rock is believed to have been caused by a tremen-



FIG. 8.—View showing shattered condition of the upper strata at the Sibley quarry, west wall. This is believed to be due to the slow creeping movement of a vast ice-sheet, combined with the subsequent action of frost.

dous weight of ice slowly and spasmodically creeping over the rock surface, the effect of which was to open up the inconspicuous sedimentation seams to a considerable depth. This permitted the entrance of water, the freezing of which would tend to completely disrupt the strata and give them the thin-bedded, shattered appearance.

SCORINGS IN MONROE COUNTY.

Eastern portion.—This county furnishes more numerous exposures of the rock surface than does Wayne, but none are

so extensive as that at the Sibley quarry. At many of the localities where rock comes to the surface it is in such weathered condition that all scoring is obliterated. In the eastern part of the county, in the vicinity of Monroe, there are six accessible localities where well preserved striæ may be studied. The most northern of these is the Sissung quarry, one and one-half miles southeast of Newport. Here the two sets of Wisconsin striæ are seen, the late Wisconsin being the more abundant and averaging N. 57° W., having swung 28° further west from their direction at Sibleys. The early Wisconsin striæ maintain nearly their same direction, averaging S. 37° W. As early as 1839 the striæ at Brest and Point aux Peaux were observed and reported upon by Bela Hubbard, an assistant upon the first geological survey of the state.¹ At the former place he found two sets N. 50° E. (S. 50° W.) and N. 65° W. At Point aux Peaux he reported but one set N. 60° E. (S. 60° W.), which is to be correlated with those of the second movement at Sibley's (Iowan?). At the present time the only striæ seen here have a general direction of S. 21° W., representing the early Wisconsin, the late Wisconsin not being exposed. Some twenty years after Hubbard's observations were made Winchell took the bearings of striæ which had been exposed by the waves at Stony Point. These he found to extend N. 60° W. and S. 60° W.² The writer now finds at this locality the two Wisconsin sets, averaging N. 54° W. and S. 10° W. At Brest the same two appear N. 57° W. and S. 9° W. At the quarry of the Monroe Stone Co., three miles southwest of Brest, the striæ average N. 48° W. and S. 12° W. Just south of the city of Monroe, at the Plum Creek quarries, we find them running N. 61° W. and S. 6° W. A comparison of the above data with those at Sibley's shows that the late Wisconsin striæ have shifted toward the west, the early Wisconsin toward the south, and that the supposed Iowan appears only at the three localities nearest the Erie shore, this representing the stoss side of the Monroe embossment for this movement. The general direction of this series is more south-

¹ *Second Ann. Rept. State Geologist*, p. 113. ² *Report for 1860*, p. 127.

westerly. At most of these localities the late Wisconsin are the most abundant, although the early Wisconsin are well represented, testifying to the more energetic nature of the latter sheet. The amount of range in the direction of the striæ of the two Wisconsin series is very notably less in this region than to the west and north. This is to be explained by the fact that we are here nearer the axis of the Huron-Erie lobe, along which the movement was theoretically only slightly divergent.

Central portion.—The only satisfactory exposure of striæ upon the central ridge of the county is found at the Woolmuth quarries, in the north central part of the county, between Maybee and Scofield, upon the Detroit & Lima Northern Railroad. The striæ of the two Wisconsin glaciations are well preserved about the main quarry, but those of the earlier series are more conspicuous. Thirteen readings give an average of S. 34.1° W., with a range of 27° (S. 22.5° W. to S. 49.5° W.). The late Wisconsin series is alone found in the small Hoffman quarry to the south. From both quarries twenty-two readings were taken and found to average N. 65.7° W., with a range of 40° (N. 91.5° W. to N. 51.5° W.). It is of interest to note that here, upon the Macon and at the Sibley quarry, some distance out from the main axis of movement, when a considerable number of observations were made, the range is from 40 to 50° , or about 25° on either side of the mean. It is not probable that doubling or trebling the number of readings would much alter the amount of this range. This amount of divergence is due to the fact that the ice moves out continually at right angles to the margin of the lobe, as pointed out some years ago by Chamberlin.¹ In the case of such a lobe as the Huron-Erie of the late Wisconsin ice, with its main line of movement toward the southwest, at any point some distance to the north of this central axis the striæ would have a more northerly course when the lobe was small and be deflected more and more to the west as the lobe increased in size. Theoretically the striæ on the northward side of the mean direction of movement should indi-

¹ *Seventh Ann. Rept. U. S. Geol. Surv.*, 1888, p. 201.

cate less vigorous ice action than the striæ upon the opposite, or westward side of this mean.

Western portion.—Upon the western rock ridge the finest exposures of striæ are to be found north of Dundee about the mouth of the Macon River. As these are in the bed of the Macon and Raisin, the best time for a visit is in the late summer or early fall when the water is low. The past season proved favorable and a satisfactory set of readings was obtained. The most conspicuous scorings to be found were made by the early Wisconsin, thirty-six observations giving a mean of S. 32.2° W., with a range of 46.5° (S. 3.5° W. to S. 50° W.). The rock ledges in the bed of the Raisin, just below the entrance of the Macon are heavily gouged by this series. The late Wisconsin sheet seems to have had but little effect upon the rock surface as the series of moraines was approached. At but one locality in the bed of the Macon are any striæ of this series to be found, giving a mean of N. 74.3° W. The movement becomes more westerly as we pass southward and south of west as the Ohio boundary is reached. At the head of Ottawa Lake a limited exposure shows the two sets S. 89° W. and S. 21° W. Just north at the quarries the few readings averaged S. 70° W. and S. 25° W. At the "Inlet" a single gouge runs S. 65° W. and three miles to the southeast in the bed of Halfway Creek four readings were obtained giving a mean of S. 56° W. In thus passing southward we approach the main axis of the late Wisconsin lobe and its striæ again predominate over those of the early Wisconsin.

GENERAL CONSIDERATIONS.

1. There is no evidence in this section of Michigan of any general southeasterly ice movement.
2. All the scoring action observed may be referred to four stages in the history of the Laurentide ice-sheet.
3. The first and oldest ice movement was to the southwest, being the most vigorous of all, quite independent of topography and presumably the most massive. Parallel with the main axis of the Illinoian glaciation its reference to this stage of the

Laurentide ice seems justified. About the western end of Lake Erie where the strike of the softer beds coincided with the direction of ice movement, broad, shallow troughs were excavated.

4. A second general movement followed west-southwesterly, intermediate in point of time between the Illinoian and early Wisconsin and less vigorous than either. This glaciation probably represents the Iowan.

5. The third ice movement was south-southwestward, second in vigor and massiveness only to the Illinoian and presumably capable of attaining also a low latitude. This is quite certainly the early Wisconsin. This ice is believed to have produced the series of outer discordant moraines in southern Ohio and Indiana. With this evidence, so far back from the southern limit of the Wisconsin ice, of distinct difference in direction of movement, in steadiness, vigor, and massiveness, more of a break between the early Wisconsin and late Wisconsin probably existed than has been yet recognized.

6. The fourth and final movement was the late Wisconsin, which resulted in the formation of the concentric morainic loops of northern Indiana, northwestern Ohio, and eastern Michigan. The ice was more influenced at this stage by the topography than at any previous time, was less vigorous and presumably less massive. The movement was in the main southwestward, but upon the upper side of the Huron-Erie lobe was outward toward the moraines, having less and less effect upon the rock surface. As the ice front retreated northeastward water was ponded back in the low country of the Maumee valley, Lake Erie region and southern Lake Huron and the series of glacial lakes was formed.

7. In the region under report the rock surface was lowered but slightly by the three later ice-sheets, the amount to be expressed most probably in inches. Knobs and trails produced by the early Wisconsin in exposed position are but slightly affected by the late Wisconsin. Moderately heavy gouges and striæ of the early Wisconsin escaped obliteration in many

localities. The relation of the striæ to the rock-basin seen in Figs. 6 and 7 shows that the adjoining rock surface was but little lowered by the early Wisconsin. In the Lake Erie region the pre-Wisconsin gouges on flat surfaces were not obliterated by both Wisconsin sheets. So far as our rock topography in this region is due to ice action this was accomplished by the first movement, that of the Illinoian. Judging from what is known concerning the rock topography of the Great Lakes region, the writer ventures to suggest as a "working hypothesis" that the real axes of all the major troughs and rock basins throughout this wide area point approximately to the Laurentide center of ice accumulation and that they were produced by the earliest of the four general movements.

W. H. SHERZER.

MICHIGAN STATE NORMAL COLLEGE,
Ypsilanti, January 30, 1902.